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ENERGY VALUES OF RED-CLOVER HAY AND MAIZE MEAL

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COOPERATIVE INVESTIGATIONS BETWEEN THE BUREAU OF ANIMAL INDUSTRY OF THE UNITED STATES DEPARTMENT OF AGRICULTURE AND THE INSTITUTE OF ANIMAL NUTRITION OF THE PENNSYLVANIA STATE COLLEGE

INTRODUCTION

The results of determinations at this institute of the net energy values for cattle of 10 different feeding stuffs or mixtures were reported by Armsby and Fries in a previous paper.[1] Attention was there called to the discordant results obtained for red-clover hay and for maize meal, and certain of them were tentatively rejected, for reasons stated, in making up the final averages. The present experiments were undertaken in order to obtain additional data concerning the energy values of these feeding stuffs. They were conducted in 1915 along the lines of the previous experiments just referred to.

GENERAL DESCRIPTION OF EXPERIMENTS

The general plan of the experiments was to feed five different rations. The first two consisted of two different amounts of red-clover hay alone, one a submaintenance ration, and the other a heavy ration. The remaining rations contained different amounts of a mixture of one-third clover hay and two-thirds maize meal, one amount being much below maintenance, one approximately maintenance, and one a heavy ration. Ten gm. of salt were added to each day's ration.

The animal used was a pure-bred Shorthorn steer, 2 years old, weighing at the beginning of the experiments a little over 500 kgm.

As in previous experiments, each feeding period covered 21 days, the first 11 being preliminary and the last 10 the digestion period proper. Table I gives the dates and the rations for the several periods and also the live weights of the animals.

[1] Armsby, H. P., and Fries, J. A. Net energy values of feeding stuffs for cattle. *In* Jour. Agr. Research, v. 3, no. 6, p. 435-491. 1915.

TABLE I.—*Duration of experiments in 1915, rations fed, and live weight of the animals*

Period No.	Preliminary period.	Digestion period.	Ration.		Live weight of steer.
			Clover hay.	Maize meal.	
			Gm.	*Gm.*	*Kgm.*
I	Jan. 3–13	Jan. 14–23	7,000	.....	513.5
II	Jan. 24–Feb. 3	Feb. 4–13	4,500	.....	497.2
III	Feb. 21–Mar. 3	Mar. 4–13	1,500	3,000	489.5
IV	Mar. 21–31	Apr. 1–10	2,500	5,000	513.5
V	Apr. 11–21	Apr. 22–May 1	1,000	2,000	491.2

The hay used was grown on the college farm and cut when in full bloom. It graded as "good hay." It was fed cut in lengths of 5 to 10 cm. The maize meal was ground from No. 2 yellow corn.

EXPERIMENTAL METHODS

The experimental and analytical methods in these experiments were the same as those previously given in detail,[1] with the exception of the determinations of carbon and hydrogen. The total carbon in the urines was determined directly by combustion of the liquid urine by a method worked out in this laboratory[2] and that of the feed and feces by combustion in a bomb calorimeter as described by Fries.[3] The organic hydrogen was not determined, as it has been found that the error resulting from omitting it entirely from the computation is very small.

Table II shows the average composition of the dry matter of the feeding stuffs used.

TABLE II.—*Composition of the dry matter of the feeding stuffs*

Feeding stuff and period No.	Ash.	Protein.	Nonprotein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Heat of combustion per kilogram.
Clover hay:	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Calories.*
I and II	5.81	8.26	1.11	34.34	48.54	1.95	4,367
III	6.20	9.49	1.25	31.40	49.33	2.34	4,403
IV and V	5.79	9.94	1.03	30.56	50.14	2.55	4,407
Average	5.93	9.23	1.13	32.10	49.34	2.28	4,393
Maize meal:							
III	1.44	9.74	.35	2.04	82.13	4.30	4,515
IV and V	1.37	9.82	.20	2.04	82.21	4.36	4,496
Average	1.41	9.78	.28	2.04	82.17	4.33	4,505

[1] Armsby, H. P., and Fries, J. A. The influence of type and of age upon the utilization of feed by cattle. U. S. Dept. Agr. Bur. Anim. Indus. Bul. 128, p. 203. 1911.

[2] Braman, W. W. A study in drying urine for chemical analysis. *In* Jour. Biol. Chem., v. 19, no. 1, p. 105–113. 1914.

[3] Fries, J. A. The determination of carbon by means of the bomb calorimeter. *In* Jour. Amer. Chem. Soc., v. 31, no. 2, p. 272–278, 1 fig. 1909.

PERCENTAGE DIGESTIBILITY OF RATIONS

From the daily records of feed and excreta and their chemical composition the percentage digestibility of the several rations has been computed in the usual manner, with the results shown in Table III.

It was assumed that in the mixed rations the hay had the percentage digestibility shown by the average of the periods when hay was fed alone, and the percentage digestibility of the maize meal in Periods III, IV, and V has also been computed, with the results shown in the last three columns of the table.

TABLE III.—*Digestibility of the rations*

Constituent.	Percentage digestibility of rations.								
	Clover hay.		Clover hay and maize meal.			Average percentage digestibility of clover hay.	Computed percentage digestibility of maize meal.		
	Period I.	Period II.	Period III.	Period IV.	Period V.	Periods I and II.	Period III.	Period IV.	Period V.
Dry matter	55.88	59.20	78.78	73.22	79.20	57.23	89.78	81.54	90.63
Ash	28.57	31.62	41.94	27.22	27.94	29.78	68.72	21.54	23.75
Organic matter	57.56	60.97	79.94	74.58	80.72	58.92	90.15	82.37	91.55
Protein	35.29	41.24	62.44	35.86	63.00	37.66	74.74	65.46	76.34
Crude fiber	50.23	53.19	54.22	47.54	46.55	51.41	76.27	17.42	8.68
Nitrogen-free extract	66.24	69.76	87.19	82.04	89.13	67.64	93.19	86.61	95.95
Ether extract	49.14	54.29	78.10	76.30	81.49	51.19	85.52	83.96	90.68
Total nitrogen	42.87	46.33	60.82	53.85	62.01	44.25	69.68	59.21	71.77
Carbon	54.10	57.50	77.85	72.41	78.32	55.46	89.32	81.25	90.23
Energy	53.80	57.20	77.28	71.87	77.65	55.15	88.29	80.40	89.12

METABOLIZABLE ENERGY

The difference between the chemical energy of the feed and that lost in the excreta shows how much of the former is capable of transformation in the animal body. This has been called metabolizable energy.

Computed in the same manner as in the earlier paper, the losses of chemical energy per kilogram of dry matter consumed and the metabolizable energy remaining were as shown in Table IV, which includes also the percentage distribution of the feed energy between the various excreta on the one hand and the metabolizable energy on the other.

The average results for the metabolizable energy per kilogram of dry matter and per kilogram of digestible organic matter are brought together for convenience in Table V.

TABLE IV.—*Losses of energy and their percentage distribution*

Feed and period No.	Dry matter eaten per head and per day.		Energy per kilogram of dry matter.				Metabolizable energy.	Metabolizable energy per kilogram of digestible organic matter.	Percentage losses.			Percentage metabolizable.
				Losses.								
	Coarse feed.	Concentrate.	Total.	In feces.	In urine.	In methane.			In feces.	In urine.	In methane.	
	Gm.	*Gm.*	*Cal.*	*Cal.*	*Cal.*	*Cal.*	*Cal.*	*Cal.*				
Clover hay:												
I	5,952	0	4,367	2,018	153	287	1,909	3,522	46.20	3.51	6.57	43.72
II	3,942	0	4,367	1,869	172	304	2,022	3,522	42.80	3.93	6.96	46.31
True average			4,367	1,958	161	294	1,954	3,522	44.85	3.68	6.72	44.75
Clover hay and maize meal:												
III	1,328	2,602	4,477	1,017	173	413	2,874	3,708	22.72	3.86	9.23	64.19
IV	2,272	4,363	4,465	1,256	136	340	2,733	3,733	28.13	3.05	7.61	61.21
V	909	1,748	4,405	998	192	495	2,780	3,546	22.35	4.30	11.09	62.26
True average			4,469	1,133	159	393	2,764	3,705	25.26	3.55	8.79	62.30
Maize meal computed:												
III	1,328	2,602	4,515	529	179	473	3,334	3,753	11.71	3.96	10.48	73.85
IV	2,272	4,363	4,496	881	133	363	3,129	3,851	19.60	3.73	8.07	69.60
V	909	1,748	4,496	489	208	599	3,200	3,543	10.88	4.63	13.32	71.17
True average			4,501	697	157	443	3,204	3,755	15.49	3.40	9.85	71.18

TABLE V.—*Average losses of chemical energy and metabolizable energy*

Feed and period No.	Gross energy per kilogram of dry matter.	Losses of chemical energy per kilogram of dry matter.	Metabolizable energy.	
			Per kilogram of dry matter.	Per kilogram of digestible organic matter.
Clover hay:	*Calories.*	*Calories.*	*Calories.*	*Calories.*
I	4,367	2,458	1,909	3,522
II	4,367	2,345	2,022	3,522
True average	4,367	2,413	1,954	3,522
Maize meal computed:				
III	4,515	1,181	3,334	3,753
IV	4,496	1,367	3,129	3,851
V	4,496	1,296	3,200	3,543
True average	4,501	1,297	3,204	3,755
Clover hay and maize meal:				
III	4,477	1,603	2,874	3,708
IV	4,465	1,732	2,733	3,773
V	4,465	1,685	2,780	3,546
True average	4,469	1,685	2,784	3,705

A comparison of the metabolizable energy per kilogram of digested organic matter as given in Table IV with the previous results shows a very close agreement, the figures being for clover hay 3.52 therms as compared with 3.49 therms, and that for maize meal 3.76 therms as compared with 3.80 therms.

INFLUENCE OF QUANTITY OF FEED CONSUMED ON LOSSES OF CHEMICAL ENERGY

A study of the percentage losses of chemical energy substantially confirms the earlier results regarding the influence of the quantity of feed upon these losses. If Periods I and II, in which a large and a much smaller hay ration were fed under similar conditions, are compared, it is seen that with the smaller ration the losses in the urine and in the methane were decidedly greater and the loss in the feces less than with the larger ration.

Periods III, IV, and V are similarly comparable, the rations of hay and maize meal being fed under the same conditions but in varying quantities. Here, as in the periods when hay alone was fed, the lightest ration shows the greatest loss in urine and methane and the least in the feces, while with the heaviest ration the reverse was true. The losses computed for the maize meal alone show differences in the same direction.

As regards variation in the percentage of total energy which was metabolizable there were slight differences. In the case of both the hay rations and the mixed rations the largest feed gave the smallest percentage, but with the mixed ration the smallest feed did not give the largest percentage. As in the experiments previously reported, the quantity of feed failed to show any definite effect upon the percentage of energy metabolized.

METHANE PRODUCTION

The relation of the methane to the digestible carbohydrates has been found to be fairly constant, so that an average figure may be used to estimate the combustible gases in the absence of the costly apparatus necessary for their actual determination.

Table VI gives this relation as actually found in these experiments.

TABLE VI.—*Quantity of methane per 100 gm. of digestible carbohydrates*

Feed and period No.	Carbohydrates.	Methane.	Methane per 100 gm. of digestible carbohydrates.	Average.
Clover hay:	*Gm.*	*Gm.*	*Gm.*	*Gm.*
I	2,940.6	127.9	4.35	4.36
II	2,054.4	89.8	4.37	
Hay and maize meal:				
III	2,689.2	121.7	4.53	4.63
IV	4,249.3	169.1	3.98	
V	1,832.4	98.6	5.38	

If these figures are compared with those of the previous experiments it is seen that while Periods I and II agree very closely, the average is somewhat lower than the earlier average for clover hay, 4.6 gm. The results from Periods III, IV, and V vary rather widely, although their average, 4.63 gm., is only a little lower than the average of the previous experiments, 4.8 gm.

HEAT PRODUCTION

The daily heat production measured and that computed in the usual manner from the balance of carbon and nitrogen are compared in Table VII.

TABLE VII.—*Observed and computed daily heat production*

Period.	Observed.	Computed.	Error.	Computed ÷ observed.
	Calories.	*Calories.*	*Calories.*	*Per cent.*
I, first day	12,238.7	12,128.7	−110.0	99.10
I, second day	12,008.4	11,634.3	−374.1	96.88
II, first day	10,389.1	10,068.9	−320.2	96.92
II, second day	10,187.1	10,148.5	− 38.6	99.62
III, first day	10,761.9	10,848.7	+ 86.8	100.81
III, second day	10,746.5	10,770.6	+ 24.1	100.22
IV, first day	13,757.7	13,574.3	−183.4	98.67
IV, second day	13,930.3	13,474.3	−456.0	96.73
V, first day	9,910.2	10,076.8	+166.6	101.68
V, second day	10,201.4	10,195.8	− 5.6	99.95

ANALYSIS OF HEAT PRODUCTION

Standing and lying have been found to exert such an influence on the heat production of animals that in order to make comparisons the observed results must be corrected to a uniform proportion of time standing and lying. The total heat production for each day of the 2-day periods has therefore been corrected to 12 hours' standing and 12 hours' lying in the manner described in the previous paper [1] and the two days averaged, and the distribution of this corrected heat production also has been computed by the method explained on page 468 of the publication just referred to.[1] The results of these computations are recorded in Table VIII.

TABLE VIII.—*Heat production per day per head corrected to 12 hours' standing*

Period No.	Dry matter eaten.		Total heat production (average of 24 hours).	Distribution of heat production.			
	Hay.	Grain.		Standing.	Rising and lying down.	Fermentation.	Remainder.
	Gm.	*Gm.*	*Cal.*	*Cal.*	*Cal.*	*Cal.*	*Cal.*
I	5,952.3	.....	12,251.3	1,584	72	777	9,818
II	3,941.5	.....	10,332.9	1,287	110	545	8,391
III	1,327.9	2,601.7	11,100.8	1,411	112	739	8,839
IV	2,271.7	4,363.0	14,129.0	1,879	127	1,026	11,097
V	908.7	1,747.5	9,854.7	1,183	113	598	7,961

[1] Armsby, H. P., and Fries, J. A. Net energy values of feeding stuffs for cattle. *In* Jour. Agr. Research v. 3, no. 6, p. 454. 1915.

ENERGY EXPENDITURE PER KILOGRAM OF DRY MATTER

A comparison of Periods I and II shows how much each additional kilogram of dry matter of the hay consumed increased the total heat production and its several factors (Table IX).

TABLE IX.—*Computation of energy expenditure per kilogram of clover hay*

Period No.	Quantity of dry matter eaten.	Total heat production	Distribution of heat production.			
			Standing.	Rising and lying down.	Fermentation.	Remainder.
	Gm.	*Cal.*	*Cal.*	*Cal.*	*Cal.*	*Cal.*
I	5,952.3	12,251.3	1,584	72	777	9,818
II	3,941.5	10,332.9	1,287	110	545	8,391
Difference	2,010.8	1,918.4	297	−38	232	1,427
Difference per kilogram of dry matter	.....	954.0	148	−19	115	710

In making the computation for the maize meal fed in Periods III, IV, and V, when hay and meal were fed, the increase in the heat production due to the differences in the quantity of hay consumed, computed by the use of the value per kilogram of dry matter just obtained, has to be subtracted from the total increment in the manner shown in the following example (Table X):

TABLE X.—*Computation of energy expenditure per kilogram of maize meal*

Period No.	Quantity of dry matter eaten.		Total heat production.	Distribution of heat production.			
	Hay.	Grain.		Standing.	Rising and lying down.	Fermentation.	Remainder.
	Gm.	*Gm.*	*Cal.*	*Cal.*	*Cal.*	*Cal.*	*Cal.*
Period IV	2,271.7	4,363.0	14,129.0	1,879	127	1,026	11,097
Period V	908.7	1,747.5	9,854.7	1,183	113	598	7,961
Difference	1,363.0	2,615.5	4,274.3	696	14	428	3,136
Difference due to 1,363.0 gm. of hay	.....	.....	1,300.3	202	−26	157	968
Difference due to 2,615.5 gm. of grain	.....	.....	2,974.0	494	+40	271	2,168
Difference per kilogram of grain	.....	.....	1,137.1	189	15	104	829

Six comparisons according to this method are possible, affording the results given in Table XI.

TABLE XI.—*Increment of heat production per kilogram of dry matter*

Feeding and period No.	Total increment.	Analysis of heat increment.			
		Standing 12 hours.	Rising and lying down.	Methane fermentation.	Remainder.
Clover hay:	*Cal.*	*Cal.*	*Cal.*	*Cal.*	*Cal.*
I–II	954	148	−19	115	710
Maize meal:					
III–II	1,253	196	−18	190	885
IV–II	1,235	192	− 3	154	892
V–II	1,382	197	−31	230	986
IV–III	1,208	186	+19	101	902
III–V	990	194	+ 8	109	679
IV–V	1,137	189	+15	104	829
Average of all	1,201	192	− 2	148	862
Average, omitting Periods III–II and II–V	1,143	190	10	117	826

The total energy expenditure per kilogram of dry matter of the clover hay, 954 Calories, agrees well with the value 992 Calories previously obtained for clover hay in experiment 179, and indicates that the very low value of 453 Calories obtained in experiment 186 was, as was suspected, erroneous.[1] It would appear that the mean of the two, 973 Calories, may be taken as the average value for red-clover hay, particularly as it is only slightly higher than that of 932 Calories computed from one of Kellner's experiments.[2]

The average figure for the total increment per kilogram of dry matter of maize meal eaten is 1,201 Calories, somewhat lower than the value of 1,434 Calories previously published. Another earlier experiment gave a value of 952 calories; but this was discarded, since the increment during lying (the "remainder" of Table XI) was only 393 Calories, as compared with 906 Calories in the experiment reported and 863 Calories, the average obtained in the present series.

Of the comparisons tabulated, however, Periods III–II and Periods II–V, are based on comparatively small differences in total heat production, so that the deduction for the energy expenditure due to the hay enters as a relatively large factor. If these two comparisons are omitted, the average of the remaining four is 1,143 Calories, which agrees closely with that of 1,137 Calories obtained from a comparison of the lightest and heaviest mixed rations (Periods IV–V), so that we are inclined to attach greater weight to this figure. The mean of this and the earlier experiment is 1,289 Calories, which may be taken as the corrected value for the heat production caused by the consumption of 1 kgm. of dry matter of maize meal by cattle.

[1] Armsby, H. P., and Fries, J. A. Op. cit., 1915, p. 473, 482.
[2] Idem., p. 478.

NET ENERGY VALUES

In computing, finally, the net energy values, by subtracting the sum of the losses of chemical energy and the energy expended in feed consumption from the gross energy of the feed, we have used first the values for the energy expended in feed consumption obtained in these experiments and then have made a second computation, using instead the average between these values and those obtained in previous experiments as computed in the foregoing paragraph. Table XII gives the final results.

TABLE XII.—*Net energy values of feeding stuffs per kilogram of dry matter*

Feed.	Gross energy.	Losses of chemical energy.	Energy expended in feed consumption.	Net energy values.
Clover hay:	*Cal.*	*Cal.*	*Cal.*	*Cal.*
These experiments	4,367	2,413	954	1,000
Mean	4,367	2,413	973	981
Maize meal:				
These experiments	4,501	1,297	1,143	2,061
Mean	4,501	1,297	1,289	1,913

SUMMARY

Results are here reported of five feeding periods with cattle, two with differing amounts of clover hay alone and three with clover hay and maize meal in differing quantities.

(1) The metabolizable energy per kilogram of digested organic matter was found to be 3.52 therms for the clover hay and 3.76 therms for the meize meal as compared with 3.49 therms and 3.80 therms, respectively, as previously reported.

(2) The average increment in heat production caused by the consumption of 1 kgm. of dry matter was as follows:

	Calories
(*a*) For clover hay	954
(*b*) For maize meal	1,143

(3) When these results are combined with those of previous experiments, the following corrected values for the average heat increment per kilogram dry matter are computed:

	Calories
(*a*) For clover hay	973
(*b*) For maize meal	1,289

(4) The average net energy values per kilogram of dry matter obtained by the use of the foregoing averages were:

	Calories
(*a*) For clover hay	981
(*b*) For maize meal	1,91

RELATIONSHIP BETWEEN THE WETTING POWER AND EFFICIENCY OF NICOTINE-SULPHATE AND FISH-OIL-SOAP SPRAYS

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INTRODUCTION

The influence of the wetting power upon the efficiency of a contact insecticide has never been entirely determined, although it has long been realized that this quality is an important limiting factor in the efficacy of certain sprays in killing insects, especially aphids, whose bodies are more or less covered with a waxy secretion. The difficulty of determining the wetting power of a solution has in the past precluded its consideration in the comparison of contact sprays in the laboratory. The present work upon the relationship of wetting power to the efficiency of nicotine and soap solutions developed from experiments performed during 1914 and 1915 in spraying garden peas (*Pisum sativum*) for the control of the green-pea aphid [(*Macrosiphum*) *Acyrthosiphum pisi* Kalt.], spinach (*Spinacia oleraceae*) for the control of the spinach aphid (*Myzus persicae* Sulz.), and strawberries (*Fragaria* sp.) for the control of red spiders (*Tetranychus* sp.). The results of the experiments demonstrated that the optimum efficiency of sprays containing nicotine sulphate and fish-oil soap was reached with a definite degree of concentration [2] and that solutions which were more concentrated and also those of lower concentration were less effective in killing the insects. In order to avoid complicated conditions, the following charts of the efficiency of the sprays are based altogether on the results of the pea-spraying experiments. The proportional efficiency of the sprays against the spinach aphids and red spiders was almost identical with the results obtained on the pea aphids.

When nicotine sulphate and fish-oil soap are mixed before they are diluted, under ordinary conditions of temperature, a precipitate may be formed. This fact has previously been noted by other authors.[3] The composition of the precipitate is probably unknown, although it is generally supposed that the resulting solutions are less effective killing agents than when the materials are mixed in dilute solutions. From observa-

[1] Detailed by the Virginia Crop Pest Commission for the investigation of insects affecting truck crops.

[2] The terms "concentration" and "concentrated solutions" as used in this paper refer to the amounts of materials called for by the various formulæ, and not to the original insecticides previous to their dilution, unless so stated.

[3] Parker, W. B. The hop aphis in the Pacific region. U. S. Dept. Agr. Bur. Ent. Bul. 111, p. 27. 1913.

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tions in the field it was noticed that certain sprays of high concentrations of soap apparently did not wet the insects as thoroughly or spread over the glaucous leaves of the pea vines as well as less concentrated soap and nicotine solutions. It was also noted that the solutions of high concentrations were not as effective insecticides as were some of the more dilute mixtures.

METHODS OF DETERMINING THE EFFICIENCY AND WETTING POWERS OF THE SOLUTIONS

The efficiency, or the killing power, of the solutions was determined from actual field-spraying experiments. Peas were sprayed five times, spinach once, and strawberries once. The experiments were performed on 27 one-twentieth-acre plots. A power sprayer which maintained a pressure of 75 to 125 pounds was used to apply the materials. Three nozzles per row were employed, two lateral and one vertical. Before the spray was applied, the number of live aphids on the vines were counted for a certain distance in the center of the plot. Two hours after spraying, another determination of the number of live insects was made on the same vines as before, and from these figures the percentage of the insects killed was computed. When spraying strawberries to control the red spider, the number of live and dead mites on several leaves from each plant were counted, and the efficiency determined in this way. Detailed results of this work are shown in Table I.

The comparative wetting powers of the spray solutions were determined by the method recommended by Cooper and Nuttall.[1] In this method a standard paraffin oil having a density of 0.8690 is run from a pipette through the solution to be tested, and the number of drops formed from a definite volume of oil are counted. The wetting power is directly proportional to the drop number. It is advisable to use distilled water as a standard liquid, as there is variation in different samples of oil; hence, the wetting power of the solutions is expressed as the ratio of the drop number of the solution to that of distilled water multiplied by 100.

The determination of the percentage of nicotine in the solutions was made by a test which was approved and adopted by the Bureau of Animal Industry on March 1, 1915. The method is well known and needs no description here.

[1] Cooper, W. F., and Nuttall, W. H. The theory of wetting, and the determination of the wetting power of dipping and spraying fluids containing a soap basis. *In* Jour. Agr. Sci., v. 7, pt. 2, p. 235. 1915.

TABLE I.—*Combined data of spraying experiments with nicotine sulphate and fish-oil soap in 1914 and 1915 at Norfolk, Va.*

Group No.	Plot.	(*Macrosiphum*) *Acyrthosiphum pisi* (5 sprayings).			Number of *Myzus persicae* killed.	Number of *Tetranychus* sp. killed.	Wetting power of solutions.	Nicotine in the sprays.
		Number alive before spraying.	Number alive after spraying.	Number killed.				
				Per ct.	*Per ct.*	*Per ct.*		*Per ct.*
1	13	1,343	336	75.0	72.5	79.6	103	0.0650
1	9	1,614	308	80.9	82.0	83.3	193	.0650
1	4	1,567	144	90.8	88.9	90.8	615	.0650
1	10	1,830	242	86.8	85.2	86.9	628	.0650
1	11	1,353	199	85.3	85.9	86.9	743	.0650
1	12	1,359	270	80.1	79.8	82.8	750	.0650
2	6	1,289	320	75.2	75.1	80.0	788	.0215
2	7	1,191	355	70.2	66.5	76.8	754	.0260
2	3	1,282	83	93.5	93.8	95.0	743	.0425
2	8	1,246	51	95.9	95.1	95.0	732	.0575
2	10	1,830	242	86.8	85.2	86.9	628	.0650
3	18	1,462	934	36.1	34.9	60.5	181	.0215
3	17	1,531	741	51.6	52.1	66.4	175	.0260
3	16	1,391	522	62.5	59.9	71.4	163	.0325
3	15	1,435	445	69.0	69.7	76.9	154	.0425
3	14	1,406	404	71.3	70.3	76.9	125	.0575
3	13	1,343	336	75.0	72.5	79.6	103	.0650
4	19	1,499	955	36.3	34.7	60.6	307	0
4	20	1,579	846	46.4	45.3	68.8	363	0
4	21	1,681	891	47.0	44.9	69.0	450	0
4	22	1,406	600	57.3	55.2	64.4	645	0
4	23	1,564	575	63.2	60.1	74.5	689	0
4	24	1,344	497	63.0	60.3	71.5	1,067	0
4	25	1,487	391	73.7	75.0	78.0	1,080	0
4	27	1,334	331	75.2	74.2	82.0	1,106	0
4	27	1,466	365	75.1	74.8	82.0	1,112	0

FORMULÆ TESTED

In the preparation of contact sprays to be applied to tender plants the concentration of the solutions is limited between a minimum which is a strength sufficient to kill all the insects which it strikes and a maximum which is the greatest concentration that can be applied without injury to the foliage. In the experiments on peas or young spinach the greatest concentration which could be used without injuring the plants was 8 pounds of soap [1] to 50 gallons of water, or a 1-to-534 concentration of nicotine sulphate. The minimum concentration was not so sharply defined.

It was the writer's endeavor to try, so far as possible, such practical combinations of the two materials as were at all likely to give satisfactory results. In order to make the formulæ more comprehensive, they

[1] A standard caustic-potash fish-oil soap was used throughout these experiments.

are placed below in their logical groups, 50 gallons of water being used in each case.

GROUP 1.—A constant amount of nicotine sulphate, with which fish-oil soap was used in varying quantities.

Plot.	Nicotine sulphate.		Fish-oil soap.
	Ounces.	*Ratio.*	*Pounds.*
13	10	1:630	1
9	10	1:630	3
4	10	1:630	4
10	10	1:630	5
11	10	1:630	6
12	10	1:630	7

GROUP 2.—A constant amount of fish-oil soap, with which nicotine sulphate was used in varying quantities.

Plot.	Fish-oil soap.	Nicotine sulphate.	
	Pounds.	*Ounces.*	*Ratio.*
6	5	3¼	1:1,938
7	5	4	1:1,575
3	5	6½	1:969
8	5	8¾	1:720
10	5	10	1:630

GROUP 3.—A minimum constant amount of soap, to which nicotine sulphate was added in varying quantities.

Plot.	Fish-oil soap.	Nicotine sulphate.	
	Pounds.	*Ounces.*	*Ratio.*
18	1	3¼	1:1,938
17	1	4	1:1,575
16	1	5	1:1,260
15	1	6½	1:969
14	1	8¾	1:720
13	1	10	1:630

GROUP 4.—Fish-oil soap used alone.

Plot.	Fish-oil soap.	Plot.	Fish-oil soap.
	Pounds.		*Pounds.*
19	2	24	5
20	3	25	6
21	3½	26	7
22	4	27	8
23	4½		

EXPERIMENTAL WORK

GROUP 1

The effectiveness of the sprays containing nicotine sulphate in the ratio of 1 to 630 with various amounts of soap to 50 gallons of solution is represented by the efficiency curve for this group in figure 1. The curve begins with 1 pound of soap to 50 gallons of spray, at 75 per cent efficiency. It gradually rises with the increased amounts of soap in the formulæ to 90.8 per cent, which is the efficacy of 4 pounds of soap plus 50 gallons of a 1-to-630 solution of nicotine sulphate. The solutions containing greater concentrations of soap than the above lose effectiveness, and the curve drops to 85.3 per cent at 6 pounds and to 80.1 per cent for the formula which contained 7 pounds of soap.

The degree of wetting of the solutions in group 1 is shown by a curve in figure 1. This is based on the arbitrary comparative values in the column at the right. The wetting power of the formula containing 1 pound of soap to 50 gallons of 1-to-630 nicotine solution is 103, the curve then rises to 193 for the formula containing 3 pounds of soap. A sudden increase in the wetting power takes place at this point, the curve going to 615 for 4 pounds, 628 for 5 pounds, 743 for 6 pounds, and 750 for 7 pounds of soap to the 50 gallons of 1-to-630 nicotine-sulphate solution.

GROUP 4

Group 4 is one of eight formulæ for fish-oil-soap solutions at ratios between 2 and 8 pounds to 50 gallons of water. The efficiency curve for group 4 is given in figure 1. The efficacy of a solution of 2 pounds of fish-oil soap to 50 gallons of water is 36.3 per cent. From this the curve rises to 73.7 per cent for a solution which contained 6 pounds of soap to 50 gallons. Greater concentration of the solutions gave but slight increase in the effectiveness, as is shown by the curve, which remains only a fraction above 75 per cent for the solutions containing 7 and 8 pounds of soap.

The wetting-power curve of the solutions in group 4 is shown in figure 1. The curve begins at 307 for the solution containing 2 pounds of soap and rises gradually to 363 for 3 pounds of soap. From this point the wetting power being greatly increased by further additions of soap, the curve rises to 645 for 4 pounds and 1,067 for 5 pounds of soap. Further concentration of the solutions increased the wetting power very little, a solution of 8 pounds of soap having the wetting value of 1,112.

DISCUSSION OF GROUPS 1 AND 4

The results of these experiments indicate (1) that the addition of nicotine sulphate to fish-oil-soap solutions decidedly increases their effectiveness in destroying aphids; (2) that the efficiency of nicotine

sprays can be increased to a considerable degree by the addition of soap, but when more than 4 pounds of soap are used to 50 gallons of 1-to-630 nicotine-sulphate solution the effectiveness of these solutions decreases;

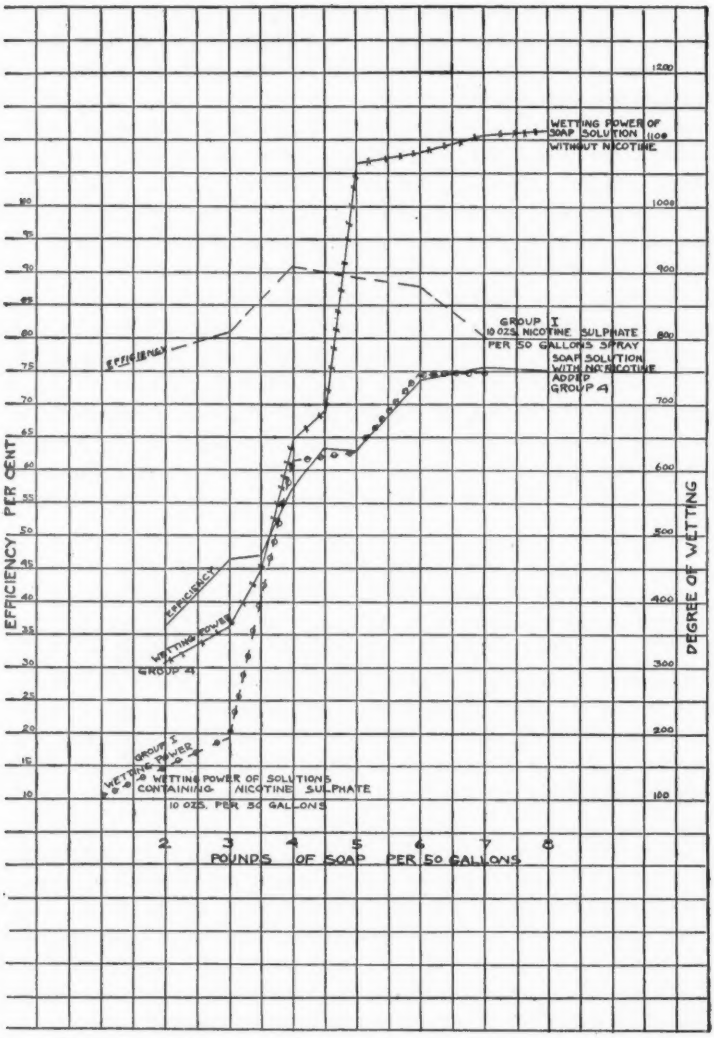

FIG. 1.—Efficiency and wetting power graphs for sprays in group 1, containing 10 ounces of nicotine sulphate and varying quantities of soap, and group 4, containing various amounts of soap with no nicotine. Wetting values are given in the column at the right.

(3) that if soap is used without the nicotine, 6 pounds to 50 gallons of water is all that can be used economically, since more concentrated solutions do not have an appreciably greater efficiency; (4) that when

nicotine sulphate at the rate of 1 to 630 is present in a soap solution the wetting power of this solution is less than that of one which contains an equal amount of soap without the nicotine; and (5) that when 4 pounds of soap or less are added to a 1-to-630 nicotine-sulphate solution the wetting power is but slightly affected by the presence of the nicotine. When more than 4 pounds of soap are added, the wetting powers of the subsequent solutions are greatly reduced from those of similar soap solutions containing no nicotine. The efficiency of the combination sprays likewise decreases from the point where the wetting power is influenced the least by the concentration.

From the foregoing statements it is evident that the addition of nicotine sulphate to soap solutions reduces the wetting power. A comparison of the wetting-power determinations of the soap solutions containing nicotine with those of the soap solutions without nicotine shows that the loss of wetting power is not by any means in direct ratio to the quantity of soap in the solution; therefore the loss is probably not entirely due to a physical effect of the nicotine upon the solution, for in that case the loss of wetting power would be proportional to the amount of soap contained in the solution before the nicotine was added. The wetting-power curves of the two groups of solutions indicate that a chemical change takes place when a certain degree of concentration is reached, which affects the physical properties of the solutions containing nicotine, and also that the effect is greater after a definite degree of concentration of soap is reached. Since all the sprays in group 1 have an efficiency of 75 per cent or more, depending on the amount of soap contained in the formula, and the highest efficiency of any of the sprays in group 4 was only slightly above 75 per cent, it is evident that the chemical reaction affects the soap and not the active nicotine sulphate. In support of this it may be stated that the solutions in groups 1, 2, and 3 were tested and it was found that the percentage of nicotine in them agreed with the amount of nicotine sulphate contained in the formulæ, and that the amount of soap present apparently had no influence upon the nicotine content of the solutions, for if any nicotine was set free by a reaction with the soap, less than 0.005 per cent was lost. This was not sufficient to cause any appreciable variation in their efficiency.

GROUPS 2 AND 3

The formulæ in group 2 contain 5 pounds of soap, which is constant for the group, plus varying quantities of nicotine sulphate to 50 gallons of water. Group 3 contains formulæ for 1 pound of soap, with similar amounts of nicotine sulphate as above, to 50 gallons of water. The efficiency and wetting-power curves for these groups appear in figure 2. The efficiency curve for group 2 rises gradually with the increased amounts of nicotine in the solution from 70 per cent at 3¼ ounces of nicotine to 93.5 per cent at 6½ ounces of nicotine in the solution. The efficiency of

8¾ ounces of nicotine was 95.9 per cent, the highest of any of the formulæ used in these experiments. This point of concentration is apparently the optimum, as the efficiency dropped to 86.8 per cent when 10 ounces of nicotine sulphate were used. The curve for the sprays in group 3 shows that the efficiency increases from 36.1 per cent for the formula containing 3¼ ounces to 69 per cent for the formula containing 6½ ounces of nicotine sulphate. From this point the efficiency rises gradually to 75 per cent for the formula containing 10 ounces of nicotine sulphate.

The wetting powers of the solutions in group 2 fall gradually from 788 for the formula containing 3¼ ounces to 732 for the formula containing 8¾ ounces of nicotine sulphate. Further concentration of the nicotine in the solution causes a considerable loss of wetting power, and the formula containing 10 ounces of nicotine has a wetting power of only 628. The wetting-power curve of the solutions in group 3 falls gradually from 181 for the formula containing 3¼ ounces to 103 for the formula containing 10 ounces of nicotine sulphate to 50 gallons of solution.

DISCUSSION OF GROUPS 2 AND 3

The main facts to be noted from the results given in figure 2 are: (1) The addition of 5 pounds of soap to the 50 gallons of nicotine solution increased the efficiency from 20 to 30 per cent more than that of similar nicotine solutions which contained only 1 pound of soap to 50 gallons of water; (2) the most efficient results were obtained with formulæ containing 5 pounds of soap, 6½ to 8¾ ounces of nicotine sulphate, and 50 gallons of water; (3) when more than 8¾ ounces of nicotine were added to the 5-to-50 soap solution there was a loss of efficiency and likewise a corresponding loss of wetting power; (4) while the quantities of soap in the solutions remained constant through both groups of formulæ, there was a gradual loss of wetting power, as the quantity of nicotine was increased in the solutions. The results derived from the formulæ in group 2 support the deductions already drawn from the results obtained with the formulæ in group 1—namely, that when certain concentrations of the soap and nicotine are reached, not only is there a decided loss of wetting power but there is also a corresponding loss in the insecticidal efficacy of the sprays. If nicotine sulphate is used at the rate of 1 to 630, the optimum efficiency is obtained with 4 pounds of soap to 50 gallons of water. By reducing the concentration of nicotine sulphate to 1 to 720, 5 pounds of soap to 50 gallons of solution gives the greater efficiency. The effect which a loss of wetting power may have upon the efficiency of a solution is indeterminable, since soap, as well as nicotine, has insecticidal properties. Thus, it is probable that a reaction which would cause a loss of wetting power would also reduce the insecticidal properties of the soap, ending in a loss of efficiency. There is

another condition which must be considered before judgment is made concerning the importance of wetting power. In case the insects are thoroughly drenched with the solution, a much higher percentage of

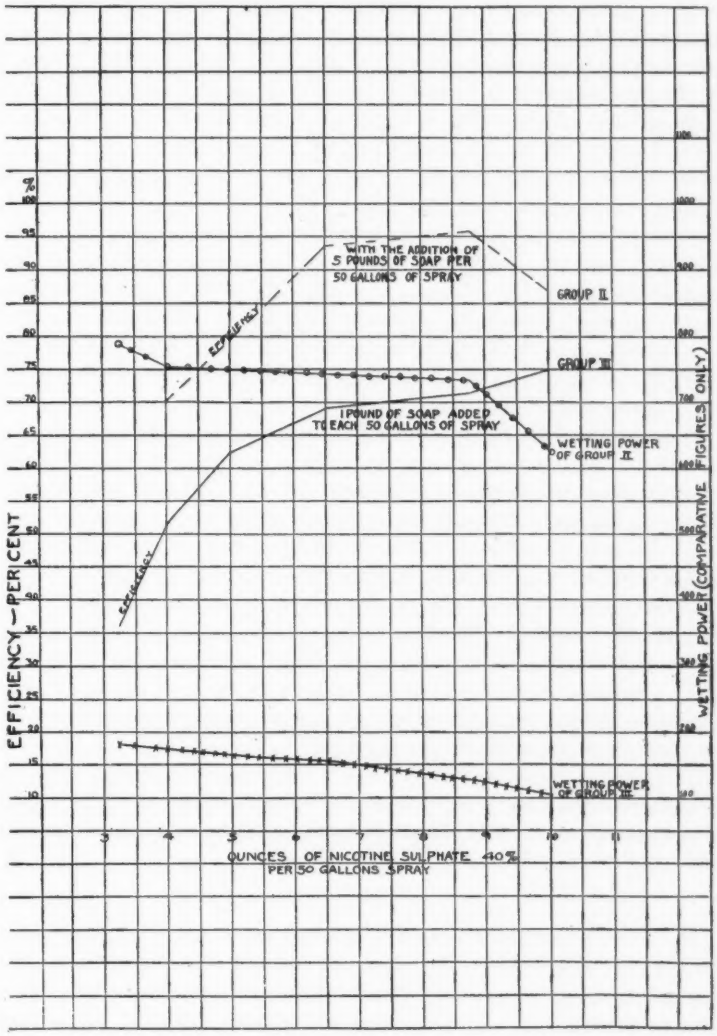

FIG. 2.—Efficiency and wetting-power gsaphs for group 2, containing 5 pounds of soap, and group 3, containing 1 pound of soap plus varying amounts of nicotine sulphate. Wetting values are in the column on the right.

mortality occurs than when the insects are struck by a few minute drops, as is usually the case in field spraying where the materials are applied at high pressure. Under the latter conditions wetting power is highly

important, for from our present knowledge the insects are killed by the absorption of the materials through the trachea, and in this case it would be necessary for the solution to spread over the body of the insect in order to gain entrance to the spiracles. A slight loss of wetting power of solutions which have an efficiency of 75 per cent or less would probably not cause an appreciable change in their effectiveness. This is shown in the case of group 3, in which the wetting power becomes less as the concentration of the solution is increased, but the efficiency rises in a normal curve. If a solution with an efficiency of 85 per cent or more upon further concentration loses wetting power, there is an appreciably greater corresponding loss of efficiency than would occur by increasing the concentrations of a solution whose efficiency is less than 75 per cent. The reason for this is obvious. A certain percentage of the insects are completely covered by the spray, so that the wetting-power influence on the efficiency is negligible; but when the insects which are struck by only a small quantity of the spray are considered, it is evident that the wetting power, as well as the strength of the solution, is an important factor governing its efficiency.

It is evident from the discussion in the preceding paragraphs that the loss of wetting power in the more concentrated mixtures is not due to a physical effect, but to chemical reactions caused by the nicotine sulphate in a soap solution. Since, if the nicotine, without causing chemical reactions, did exert an influence on the physical properties of the solutions, the loss of wetting power would be directly proportional to the amount of soap in the solution and also to the wetting powers of the soap solutions which contained no nicotine. Likewise, the loss of efficiency in the concentrated solutions is not due to a reaction which would cause a portion of the nicotine to be liberated as free nicotine, for the nicotine contents of the solutions were determined and the percentages were found to remain constant irrespective of the amounts of soap added to the solutions. From these facts we are led to assume that either a direct loss of wetting power or a reduction of the insecticidal value of the soap or both are contributing factors in the loss of efficiency of the more concentrated nicotine-sulphate and fish-oil-soap solutions.

SUMMARY

(1) When using combination fish-oil-soap and nicotine-sulphate sprays for the control of insects affecting truck crops, it was found that certain concentrated mixtures did not give as satisfactory results as did some of lower concentration. In connection with these results it was noticed during the spraying operations that some of the more concentrated solutions did not possess as high wetting or spreading powers as other mixtures which contained less soap.

(2) The spraying operations were performed on peas, spinach, and strawberries against the pea aphid, spinach aphid, and red spider,

respectively. The proportional efficiency of the sprays proved to be similar for each species. The efficiency of the sprays was determined by counting the number of live insects on a portion of the plot previous to the application of the sprays, and again determining the number two hours after treatment. The experiments were performed on 27 one-twentieth-acre plots. Peas were sprayed five times, spinach and strawberries once. The wetting powers as well as the nicotine content of the solutions were determined.

(3) When more than 4 pounds of soap were used with 10 ounces of nicotine sulphate to 50 gallons of water, there was a loss of both wetting power and efficiency.

(4) When more than 8¾ ounces of nicotine sulphate were combined with 5 pounds of fish-oil soap to 50 gallons, a loss occurred in both the wetting power and the efficiency.

(5) When nicotine sulphate was used in quantities up to 10 ounces, to a 1-to-50 fish-oil-soap solution, none of the resultant sprays had an efficiency of more than 75 per cent. Also, when fish-oil soap was used alone in quantities not exceeding 8 pounds to 50 gallons, the highest efficiency of any of the formulæ was only a fraction over 75 per cent.

(6) It was found that the nicotine content of the solutions remained the same irrespective of the amount of soap used.

(7) The loss of efficiency due to increasing the concentrations of the solutions is probably caused by a loss of both wetting power and insecticidal value of the soap.

(8) The loss of wetting power which occurs when the concentration of the solutions is increased has a stronger tendency to reduce the efficiency of the subsequent solutions, if the original solution has an efficiency of 85 per cent or more, than it does if the original efficiency is below 75 per cent.

(9) The actual importance of wetting power is difficult to determine in this case, as the fish-oil soap has insecticidal properties in itself. Where the wetting power is affected, it is probable that the soap is also broken down sufficiently to lose some of its value as an insecticide; hence, both factors must be considered as the cause of the loss of efficiency of some of the more concentrated mixtures.

LIFE HISTORY AND POISONOUS PROPERTIES OF CLAVICEPS PASPALI

By H. B. BROWN,[1]

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INTRODUCTION

During the last decade *Paspalum dilatatum* Poir. has attained considerable prominence as a forage grass in various parts of the South. One serious objection to its use, however, is that forage poisoning frequently results among cattle feeding on it. Brown and Ranck[2] showed that the poisonous property is due to *Claviceps paspali* Stevens and Hall, a fungus that infects the grass very generally. This species was described by Stevens and Hall[3] in 1910. Norton[4] observed this fungus on *P. dilatatum* in Maryland in 1902. He suspected that it was poisonous, but carried on no feeding experiments to determine this.

Since September, 1914, the writer has been making a study of the life history of *Claviceps paspali* and its growth and distribution in the region about the Mississippi Agricultural College. In this region the fungus infects *Paspalum dilatatum* very generally, a few weeks after the grass heads out at least 90 per cent of the old heads showing infection.

LIFE HISTORY OF THE FUNGUS

Sclerotia produced during the summer and autumn (Pl. 32, F) drop to the ground when the old grass head sheds its spikelets, and lie on the ground until spring. They may be found at any time during the winter and spring by searching in the litter on the ground where infected *Paspalum dilatatum* grew the season before. Sclerotia gathered during the winter and placed in moist chambers kept at room temperature will germinate in 20 to 30 days, but it is the writer's experience that sclerotia forced in this way do not produce as many nor as large and vigorous stromata as those that germinate in the normal way. After a few days of rainy weather about the middle of May, sclerotia germinating on the ground may be expected. They were first found

[1] I wish to express my obligation to Dr. Charles F. Briscoe and to Prof. J. M. Beal, of the Mississippi Experiment Station, for the use of their laboratories in carrying on this work, and for other courtesies extended to me.

[2] Brown, H. B., and Ranck, E. M. Forage poisoning due to Claviceps paspali on Paspalum. Miss. Agr. Exp. Sta. Tech. Bul. no. 6, 35 p., 18 fig. 1915.

[3] Stevens, F. L., and Hall, J. G. Three interesting species of Claviceps. *In* Bot. Gaz., v. 50, no. 6, p. 460-463, 8 fig. 1910.

[4] Norton, J. B. S. Plant diseases in Maryland in 1902. *In* Rpt. Md. State Hort. Soc., v. 5, 1902, p. 90-99. [1902.]

on May 10 in 1915 and on May 21 in 1916. In each case this was just after the host plant had begun to flower.

The sclerotia of *Claviceps paspali* when mature are globular in shape, 2 to 4 mm. in diameter, irregularly roughened on the surface, and yellowish gray in color; the interior is homogeneous in structure and contains a considerable quantity of oil. Germinating sclerotia produce from one to several stromata, usually two or three, with slender whitish stalks 3 to 15 mm. in length, and heads about 1 mm. in diameter (Pl. 32, E). The heads are roughened over the surface owing to projecting perithecial necks (Pl. 32, A, E), and are at first whitish in color, later becoming rather bright yellow, and finally brownish.

A vertical section of a stromatic head (Pl. 32, A) shows numerous flask-shaped perithecia embedded in the outer part of the head. The neck of each perithecium projects a short distance beyond the surface, thus forming small pimple-like projections. Each perithecium contains numerous slender, cylindrical asci, 150 to 170μ in length (fig. 1, *a*); at the outer end of each ascus there is a thimble-like knob fitting over the end. The wall of the ascus is so thin that it can not be distinguished clearly. The ascospores are filiform and hyalin, being a little less than 1μ in diameter and 70 to 100μ in length (fig. 1, *c*). There are probably eight spores in an ascus, although not more than seven were counted with certainty. It was not possible to count the spores when inside an ascus, as they are hyalin and packed together closely, and it was a rather difficult matter to count them as the ascus disintegrated.

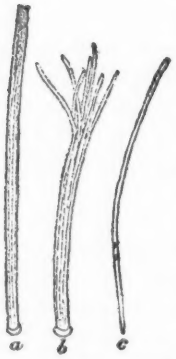


FIG. 1.—*Claviceps paspali*: *a*, Mature ascus; *b*, ascus breaking up to liberate spores; *c*, ascospore.

Mature stromatic heads from sclerotia just gathered from the field when allowed to dry slightly and then moistened exuded asci very freely. The asci go to pieces quickly after escaping from the perithecia and liberate the spores. A change of moisture conditions in the field will cause spores to be deposited on the surface of the stromatic head, where they are in position to be picked up by insects that chance to rub against the head. The stromata are somewhat tough and leathery and last for several days. If the ground becomes dry during their regular period they dry out, but revive with the coming of moisture and again shed spores. No stromata were found in the field after July 2.

Flowers of *Paspalum dilatatum* inoculated with ascospores by rubbing stromatic heads against stigmas and spikelets of the grass heads showed abundant evidence of infection in seven days. Flowers on control plants showed no infection. (Both inoculated plants and controls were kept under bell jars.) In the field, infected heads are not found for several days after the sclerotia germinate. They were first noticed on June 8 in

1915 and on June 12 in 1916, being, respectively, 29 and 22 days after germinating sclerotia were first found. In 1915, infected or diseased heads were not plentiful in the fields until about July 12. Preceding this date there were several days of rainy weather. In 1916, similar observations were made. Diseased heads became very common during July, following several weeks of rain. On August 1, 1916, they were more plentiful than since the autumn of 1914.

In the fields the first infection of the season is doubtless carried by insects. Running over the ground, they are likely to rub against the stromatic heads, which are covered with ascospores, and, climbing up the grass culms to take flight, may carry ascospores to the grass flowers and produce infection. That infection does not take place often is evidenced by the fact that the disease is slow in getting a start after the sclerotia germinate.

FIG. 2.—*Claviceps paspali*: Tip of tuft of hyphæ, showing the production of sphacelia spores.

The infecting fungus attacks the pistil of the grass flower, and in a few days the ovary is almost entirely destroyed, a mass of fungus tissue filling the space it occupied. Plate 32, D, shows a section of the mass of fungus tissue between the glumes of a grass spikelet a week after infection. The two spots in the central part of the figure represent remnants of the grass flower. The rest of the central part of the section is homogeneous tissue, while around the edge are numerous tufts of hyphæ standing at right angles to the central mass. Figure C of Plate 32 shows the tufts enlarged. Each tuft contains a number of hyphæ. The digital ends of these hyphæ, or certain of them, enlarge and form conidia or sphacelia spores. Figure 2 shows the tip of a tuft of hyphæ. The spores are hyalin but show granules when stained, oblong, about 5μ wide and 15μ long. They are produced in great abundance and are carried from the hyphæ on which they were produced by a droplet of honeydew, a sticky, sweetish exudation of the fungus tissue. Insects of many kinds feed on this honeydew and carry infection by means of the spores clinging to their bodies. Hand inoculations, which were made by smearing honeydew containing sphacelia spores on flower stigmas, produced infections that were exuding honeydew and sphacelia spores freely within the space of a week. This result was obtained in the case of plants kept under bell jars, and also with plants inoculated in the field. Sphacelia spores frequently germinate in the droplet of honeydew and give it a whitish appearance.

The sphacelia stage in which honeydew is exuded lasts but a few days. If the weather is dry, the whole grass head is likely to become dry and dead, and no further development occurs. Or, again, honeydew may become infected with a species of Fusarium or Cladosporium and growth be stopped. If weather conditions are favorable, the solid mass of fungus tissue, constituting the bulk of the sphacelia tissue, continues to enlarge and soon forces the glumes of the spikelets apart. These masses are young sclerotia. In some cases within a week after the sphacelia stage was at its height the young sclerotia were projecting from between the glumes of the spikelet and were 1 to 2 mm. in diameter. Following this, some of the sclerotia continue to enlarge, attaining a maximum diameter of about 4 mm. and characters as outlined above. During September and October the largest sclerotia are to be found; sclerotia are also most plentiful then.

OTHER FUNGI INFECTING PASPALUM DILATATUM

As was mentioned above, *Fusarium heterosporum* Nees. and *Cladosporium* sp. are two other fungi found infecting heads of *Paspalum dilatatum*. While these fungi have not been studied carefully, they seem to be largely in the nature of molds growing on *Claviceps paspali* and parts of the diseased grass heads. The inoculation of healthy grass heads with spores from pure cultures of each of these fungi produced no infection. They are probably of no great consequence.

POISONOUS PROPERTIES OF CLAVICEPS PASPALI

As was shown by Brown and Ranck,[1] *Claviceps paspali* is poisonous to certain animals, especially to cattle and guinea pigs. It produces a peculiar nervousness, resembling considerably that shown in certain stages of rabies, and if eaten in quantity may cause death. A gram of extract made from this fungus, although probably containing other substances in addition to the poisonous element, will, if fed to a guinea pig, cause death within a few hours. Many cattle running on pastures in which the diseased grass is plentiful perish when under the influence of the poison by getting down in the pasture out of reach of water and feed. A good many others, too, perish by drowning in pools or ponds of shallow water. They fall into the water in a nervous paroxysm and drown before getting over it.

Guinea pigs used in feeding experiments showed nervousness after being fed 50 sclerotia that had been picked from old heads of *Paspalum dilatatum*. Continued feeding produced death within a week or less. In most cases the sclerotia were given in doses of 25 a day.

In feeding experiments carried on during the summer of 1915 it was found that sclerotia that had been in the laboratory for about 10 months

[1] Brown, H. B., and Ranck, E. M. Forage poisoning due to Claviceps paspali on Paspalum. Miss. Agr. Exp. Sta. Tech. Bul. 6, 35 p., 18 fig. 1915.

were still poisonous and that a small amount of the extract of *Claviceps paspali* exposed to air and hot summer temperature was still active after a period of about 10 months.

A guinea pig fed 40 grass spikelets daily for seven days, each containing a mass of *Claviceps paspali* tissue in the sphacelia, or honeydew, stage, and 60 each day for the next 36 days, showed no bad effects, but gained in weight. Another pig fed 25 young sclerotia daily for 7 days and 40 daily for the next 21 days showed no bad effects, but gained in weight slightly. This feeding was started on July 16. The last two experiments seem to indicate that it is only the old sclerotia that are poisonous. The experience of farmers with cattle on pastures indicates the same.

Mowing pastures one or more times during the late summer or autumn, or as often as mature sclerotia become abundant, is an effective method of preventing poisoning, and is a measure of practical value in most places.

PLATE 32

A.—Section through a mature stromatic head of *Claviceps paspàli*, showing perithecia containing asci. ×45.

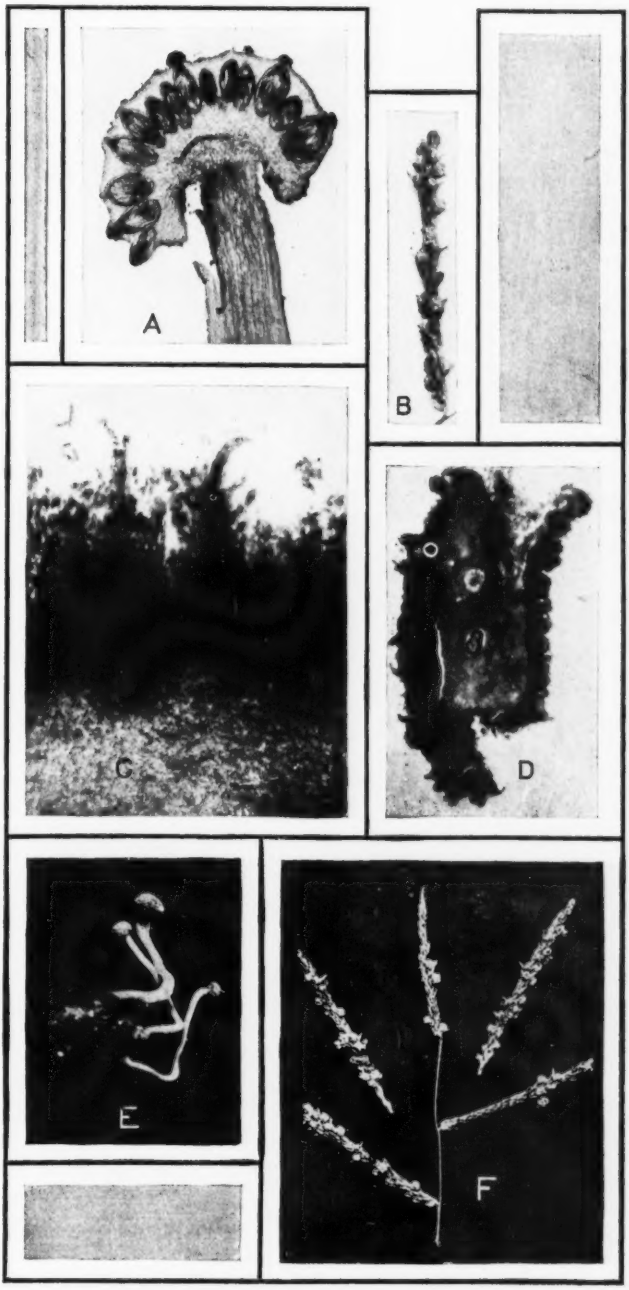
B.—Spike of *Paspalum dilatatum* with mature sclerotia attached. Nearly natural size.

C.—Tufts of hyphæ producing sphacelial spores. ×150.

D.—Section of mass of tissue within grass spikelet during sphacelia stage of *Claviceps paspali;* spores are produced by tufts of hyphæ along edge of section. ×50.

E.—Sclerotium of *Claviceps paspali* with stromata. ×5.

F.—Spikes of *Paspalum dilatatum*, showing a number of sclerotia attached. About one-half natural size.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EFFECT OF SODIUM SALTS IN WATER CULTURES ON THE ABSORPTION OF PLANT FOOD BY WHEAT SEEDLINGS

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INTRODUCTION

The following experiments were undertaken to determine the extent to which the presence of the various sodium salts commonly found in alkali soils affects the absorption of plant-food elements by wheat seedlings. Sodium chlorid, sodium sulphate, and sodium carbonate in concentrations ranging from 50 to 1,000 p. p. m.[1] were employed in connection with a standard nutrient solution, consisting of 200 p. p. m. of NO_3 as sodium nitrate, 200 p. p. m. of K_2O as potassium chlorid, and 130 p. p. m. of P_2O_5 as sodium phosphate, together with calcium carbonate ($CaCO_3$) in excess. The same variety of hard wheat, Minnesota Bluestem C. I. 169 (*Triticum vulgare*), was used in all the measurements.

CULTURE METHOD

The enameled culture pans each contained 2,500 c. c. of the nutrient solution. Each pan was provided with a perforated aluminum disk, supported on sealed glass buoys, so as to float at the surface of the solution. Wheat seeds were sprinkled over the disks in numbers sufficient to provide about 1,000 seedlings in each pan.

The nutrient solution in each pan was changed every two days and during the intervening period was kept approximately at the original volume by the addition of water. The analyses showed that with this method of procedure there was always an abundance of plant food at the disposal of the seedlings.

During the first two days of the experiment the seedlings were grown in the nutrient solution alone. At the end of the second day sodium chlorid, sodium sulphate, and sodium carbonate were added to the nutrient solution in concentrations varying from 50 to 1,000 p. p. m., as shown in Tables I to IV. The sodium carbonate in the lower concentrations gradually changed to sodium bicarbonate, owing to the absorption of carbon dioxid from the atmosphere and to its evolution from the roots of the growing seedlings. Where the original concentration was 300 p. p. m. and above, sodium carbonate was still present after the plants had been grown in the culture solution for two days.

[1] Parts per million in solution by weight.

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The cultures were carried on for 21 days in the sunshine at Riverside, Cal. At the end of this period the green and dry weights of 100 representative plants from each culture pan were determined, and the plants were analyzed by official methods for nitrogen, phosphoric acid, and potash. The results are given in Tables I, II, III, and IV, the weight in each instance being based upon 100 plants.

SODIUM CHLORID

The experimental data obtained with nutrient solutions containing graduated amounts of sodium chlorid are given in Table I, and in figure 1 the quantities of potash, phosphoric acid, and nitrogen contained in 100 plants are plotted separately against the sodium-chlorid concentration. The presence of sodium chlorid in the nutrient solution appears to

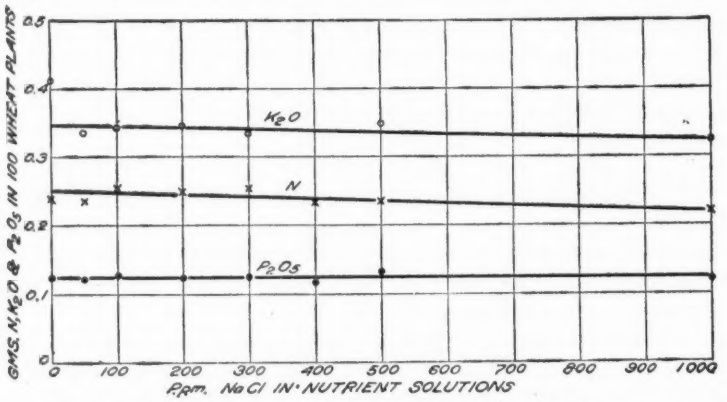

FIG. 1.—Graphs showing the effect of sodium chlorid in nutrient solutions on the nitrogen, potash, and phosphoric-acid content of wheat seedlings.

diminish very slightly the potash and nitrogen content of the wheat plants, but the effect is so small as to be comparable with experimental errors. The phosphoric-acid content of the wheat seedlings appears to be quite independent of the amount of sodium chlorid in the culture solution for the range in concentration here employed.

The nitrogen, potash, and phosphoric-acid content of the seedling wheat plants grown in the presence of sodium chlorid are also expressed in Table I in percentage of the dry weight of the plants. The results in this form are not as concordant as those already discussed, but lead to the same conclusion—namely, that the presence of sodium chlorid in culture solutions in graduated concentrations up to 1,000 p. p. m. has very little effect upon the total nitrogen, potash, and phosphoric-acid content of young wheat plants.

TABLE I.—*Effect of sodium chlorid on the weight and composition of wheat seedlings*

Culture No.	Parts per million of sodium chlorid added to nutrient solution.	Green weight of 100 plants.	Dry weight of 100 plants.	Weight of element in 100 plants.			Percentage of dry weight of plants.		
				N.	K_2O.	P_2O_5.	N.	K_2O.	P_2O_5.
		Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*			
1	0.....	71. 5	6. 21	0. 240	0. 411	0. 125	3. 9	6. 6	2. 0
2	50.....	59. 5	5. 70	. 236	. 334	. 119	4. 1	5. 9	2. 1
3	100.....	58. 5	5. 70	. 252	. 343	. 125	4. 4	6. 0	2. 2
4	200.....	61. 5	5. 70	. 249	. 345	. 124	4. 4	6. 1	2. 2
5	300.....	63. 5	5. 70	. 251	. 332	. 125	4. 4	5. 8	2. 2
6	400.....	64. 5	5. 96	. 230	. 288	. 115	3. 9	4. 8	1. 9
7	500.....	59. 0	5. 29	. 231	. 348	. 133	4. 4	6. 6	2. 5
8	1,000.....	56. 6	5. 55	. 216	. 322	. 121	3. 9	5. 8	2. 2

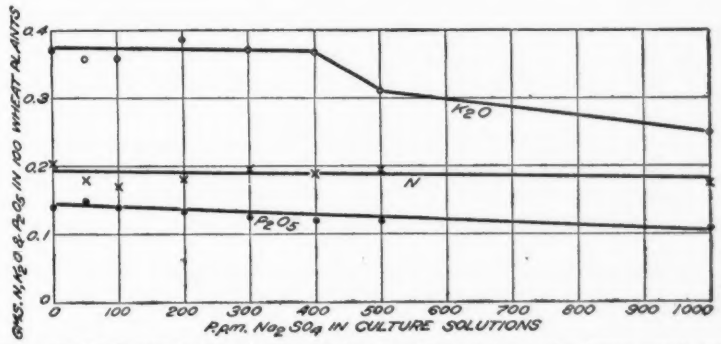

FIG. 2.—Graphs showing the effect of sodium sulphate in nutrient solutions on the nitrogen, potash, and phosphoric-acid content of wheat seedlings.

SODIUM SULPHATE

The data obtained with culture solutions containing graduated amounts of sodium sulphate are given in Table II. The results of the analyses of the plants for nitrogen, potash, and phosphoric acid are given both in terms of the actual amounts found in 100 plants from each culture and also in percentage of the dry weight of the plants. The dry weight is nearly uniform, so that the percentage relationship does not differ materially from that represented by the absolute amounts of nitrogen, potash, and phosphoric acid found. The latter determinations are plotted as ordinates in figure 2 and the concentration of sodium sulphate in the culture solutions as abscissæ. The results show that the addition of sodium sulphate to the nutrient solution in concentrations up to 1,000 p. p. m. has practically no effect on the total nitrogen content of the young wheat plants. In concentrations greater than 400 p. p. m. the sodium sulphate depressed the potash content slightly. In the case of phosphoric acid the plants show a very slight but steady decrease in the

total phosphoric-acid content as the concentration of the sodium sulphate increases. This effect is in evidence throughout the range of sodium-sulphate concentrations employed.

TABLE II.—*Effect of sodium sulphate on the weight and composition of wheat seedlings*

Culture No.	Parts per million of sodium sulphate added to nutrient solution.	Green weight of 100 plants.	Dry weight of 100 plants.	Weight of element in 100 plants.			Percentage of dry weight of plants.		
				N.	K_2O.	P_2O_5.	N.	K_2O.	P_2O_5.
		Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*			
1	0	63. 1	5. 85	0. 206	0. 369	0. 141	3. 5	6. 3	2. 4
2	50	67. 0	6. 07	. 178	. 367	. 150	2. 9	6. 0	2. 4
3	100	69. 4	6. 23	. 163	. 367	. 140	2. 6	5. 9	2. 2
4	200	66. 6	5. 75	. 181	. 385	. 133	3. 1	6. 7	2. 3
5	300	67. 2	6. 08	. 194	. 370	. 125	3. 2	6. 1	2. 1
6	400	65. 5	6. 13	. 184	. 367	. 120	3. 0	6. 0	2. 0
7	500	62. 5	5. 75	. 194	. 311	. 120	3. 4	5. 4	2. 1
8	1,000	59. 0	5. 75	. 176	. 248	. 106	3. 1	4. 3	1. 8

SODIUM CARBONATE

The data obtained with culture solutions containing sodium carbonate are presented in Table III. The absolute quantities of potash, nitrogen, and phosphoric acid found in 100 seedlings are plotted in figure 3 against

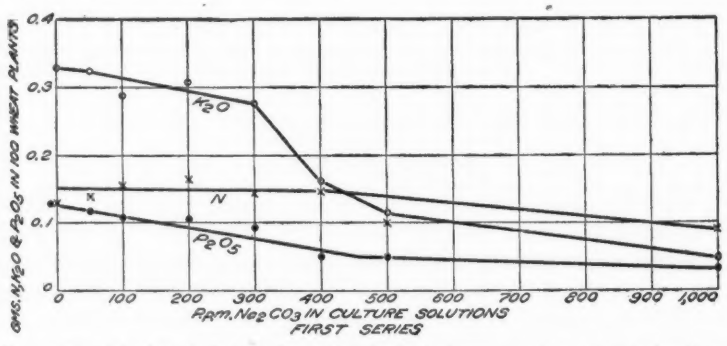

FIG. 3.—Graphs showing the effect of sodium carbonate on the nitrogen, potash, and phosphoric-acid content of wheat seedlings. First series.

the sodium-carbonate concentration. The results show a marked reduction in the amount of potash and phosphoric acid in the seedlings as the concentration of the sodium carbonate increases, the total potash or phosphoric-acid content of 100 wheat plants grown in the presence of 1,000 p. p. m. of sodium carbonate being only one-third that of the plants grown in the control solutions. The total nitrogen content of the wheat plants is also slightly decreased.

TABLE III.—*Effect of sodium carbonate on the weight and composition of wheat seedlings*

FIRST SERIES

Culture No.	Parts per million of sodium carbonate added to nutrient solution.	Green weight of 100 plants.	Dry weight of 100 plants.	Weight of element in 100 plants.			Percentage of dry weight of plants.		
				N.	K_2O.	P_2O_5.	N.	K_2O.	P_2O_5.
		Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*			
1	0	60.3	5.59	0.128	0.329	0.130	2.3	5.8	2.3
2	50	61.0	5.65	.139	.327	.118	2.5	5.8	2.1
3	100	53.6	4.89	.156	.287	.108	3.2	5.9	2.2
4	200	53.2	4.93	.164	.307	.105	3.3	6.2	2.1
5	300	50.5	4.92	.140	.275	.093	2.9	5.6	1.9
6	400	32.7	3.36	.148	.158	.050	4.4	4.7	1.5
7	500	28.0	3.81	.098	.113	.049	2.6	2.9	1.3
8	1,000	15.5	2.77	.087	.047	.037	3.2	1.7	1.3

SECOND SERIES

1	0	71.5	6.21	0.240	0.411	0.125	3.9	6.6	2.0
2	50	57.5	5.61	.230	.332	.115	4.1	5.9	2.1
3	100	57.5	5.42	.257	.331	.116	4.7	6.1	2.1
4	200	52.5	5.11	.209	.359	.101	4.1	7.0	2.0
5	300	40.5	4.42	.160	.291	.097	3.6	6.6	2.2
6	400	31.8	4.25	.125	.230	.067	2.9	5.4	1.6
7	500	36.5	4.11	.144	.144	.057	3.5	3.5	1.4
8	1,000	20.5	3.16	.110	.061	.046	3.5	1.9	1.5

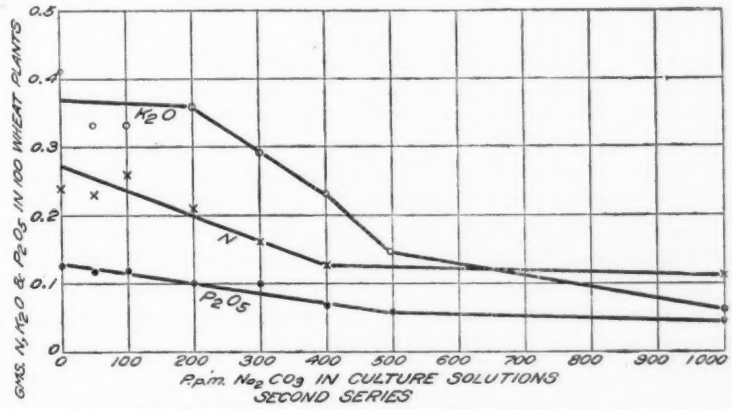

FIG. 4.—Graphs showing the effect of sodium carbonate on the nitrogen, potash, and phosphoric-acid content of wheat seedlings. Second series.

These results are in such striking contrast with the effects obtained with the other sodium salts that the sodium-carbonate series was repeated. The results of the second series of determinations are also given in Table III and are presented graphically in figure 4. A marked reduc-

tion in the potash and phosphoric-acid content is again shown as the sodium-carbonate concentration increases. In this series also there is a decided reduction in the total nitrogen content with increasing concentration of the sodium carbonate.

Reference to Table III will show that the weight of the seedlings decreased markedly as the concentration of the sodium carbonate increased. It is consequently of interest to express the nitrogen, potash,

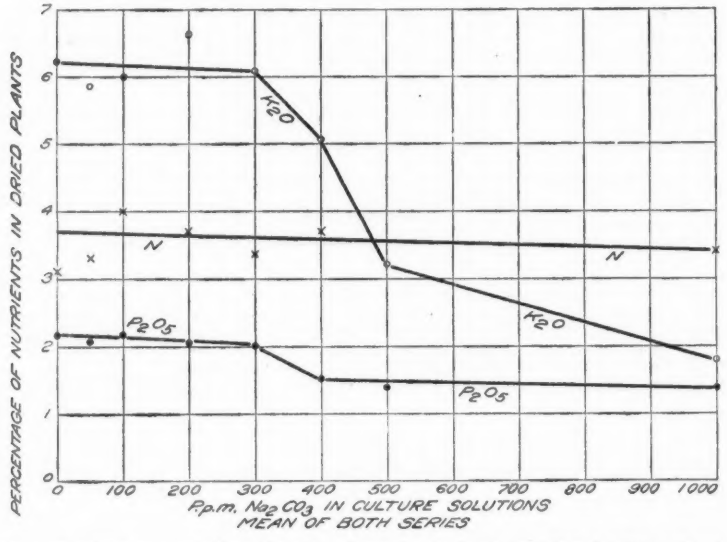

FIG. 5.—Graphs of the mean values of the first and second series showing the effect of sodium carbonate on the nitrogen, potash, and phosphoric-acid content expressed in percentage of the dry weight of wheat seedlings.

and phosphoric-acid content of the seedling plants in percentage of their dry weight. The results computed on this basis will be found in the last three columns of the table. The mean values for both series of determinations are plotted in figure 5. It will be seen that the percentage of nitrogen does not show any consistent change as the concentration of the sodium carbonate increases. The percentages of potash and phosphoric acid, on the other hand, decrease markedly with increasing concentration of the sodium carbonate.

NITROGEN, POTASH, AND PHOSPHORIC ACID ABSORBED FROM THE NUTRIENT SOLUTION BY THE VARIOUS CULTURES

The data so far given include the nitrogen, potash, and phosphoric acid stored in the seed. The analysis of 100 seeds for these substances gave the following results:

	Gram.
Weight of 100 seeds (dry)	2.45
Nitrogen	.0486
Potash (K_2O)	.0185
Phosphoric acid (P_2O_5)	.0242

If it is assumed that each lot of 100 seeds is of uniform composition and weight, the amount of nitrogen, potash, and phosphoric acid absorbed from the nutrient solutions by the various cultures can be determined by deducting the above quantities from those found in the plants grown in the culture solutions. The data obtained from the various cultures, reduced to this basis, are given in Tables V and VI, and are presented graphically in figures 6 to 8, the last figure representing the mean of the two sodium-carbonate series.

TABLE V.—*Effect of sodium chlorid and sodium sulphate on the absorption of nutrients by wheat seedlings*

Culture No.	Sodium chlorid.				Sodium sulphate.			
	Sodium chlorid added to nutrient solution.	Elements absorbed from solution (in percentage of dry weight of plants).			Sodium sulphate added to nutrient solution.	Elements absorbed from solution (in percentage of dry weight of plants).		
		N.	K_2O.	P_2O_5.		N.	K_2O.	P_2O_5.
	P. p. m.				*P. p. m.*			
1	0	3.1	6.3	1.7	0	2.8	6.0	2.0
2	50	3.3	5.5	1.7	50	2.1	5.7	2.1
3	100	3.6	5.7	1.9	100	1.8	5.6	1.9
4	200	3.5	5.9	1.8	200	2.3	6.4	1.9
5	300	3.6	5.5	1.9	300	2.4	5.8	1.8
6	400	3.0	4.5	1.5	400	2.2	5.7	1.6
7	500	3.5	6.6	2.1	500	2.5	5.1	1.7
8	1,000	3.0	5.5	1.7	1,000	2.2	4.0	1.4

The percentage of nitrogen absorbed by the young wheat plants does not appear to be measurably modified by the presence of any of the sodium salts investigated in concentrations up to 1,000 p. p. m. Sodium chlorid in this concentration does not affect the absorption of phosphoric acid measurably (fig. 6), but depresses slightly the percentage of potash absorbed. Sodium sulphate depresses the absorption of potash decidedly and of phosphoric acid slightly (fig. 7), while with sodium carbonate the depression in the absorption of both potash and phosphoric acid is very marked (fig. 8). The depressing effect of sodium carbonate on the

absorption of potash and phosphoric acid is in evidence even in concentrations of sodium carbonate as low as 100 p. p. m. It is evident

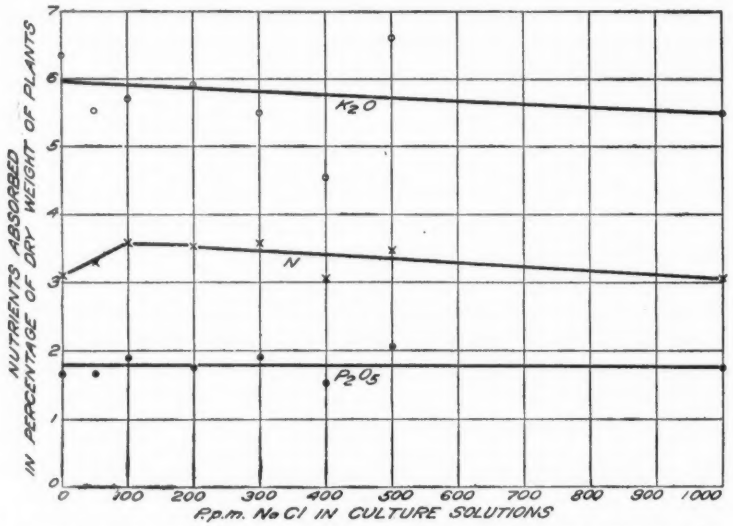

FIG. 6.—Graphs showing the effect of sodium chlorid on the absorption of nutrients by wheat seedlings.

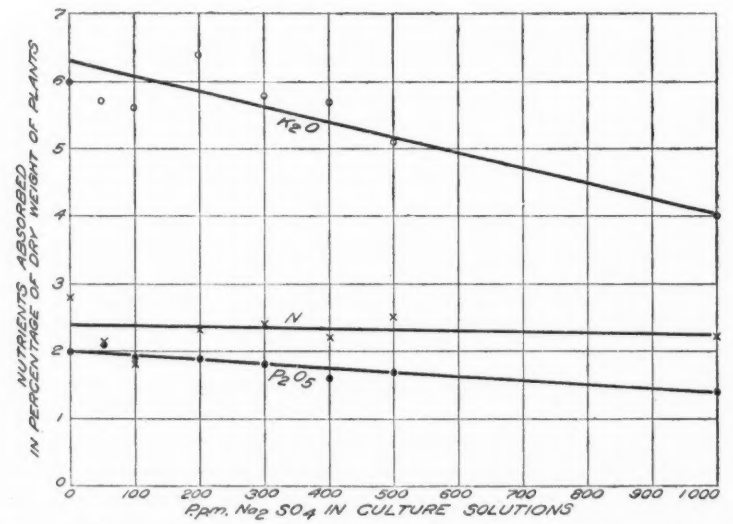

FIG. 7.—Graphs showing the effect of sodium sulphate on the absorption of nutrients by wheat seedlings.

from these measurements that the presence of sodium carbonate, even in these minute amounts, may have a markedly deleterious effect upon the metabolism of the small-grain crops.

TABLE VI.—*Effect of sodium carbonate on the absorption of nutrients by wheat seedlings*

FIRST SERIES

Culture No.	Sodium carbonate added to nutrient solution.	Elements absorbed from solution (in percentage of dry weight of plants).		
		N.	K_2O.	P_2O_5.
	P. p. m.			
1	0	1.4	5.6	1.9
2	50	1.6	5.6	1.7
3	100	2.2	5.5	1.7
4	200	2.3	5.9	1.6
5	300	1.9	5.2	1.4
6	400	3.0	4.2	.8
7	500	1.3	2.5	.7
8	1,000	1.4	1.0	.4

SECOND SERIES

1	0	3.1	6.3	1.7
2	50	3.2	5.6	1.6
3	100	3.9	5.8	1.7
4	200	3.1	4.7	1.5
5	300	2.5	6.2	1.6
6	400	2.0	5.0	1.0
7	500	2.3	3.0	.8
8	1,000	1.9	1.3	.7

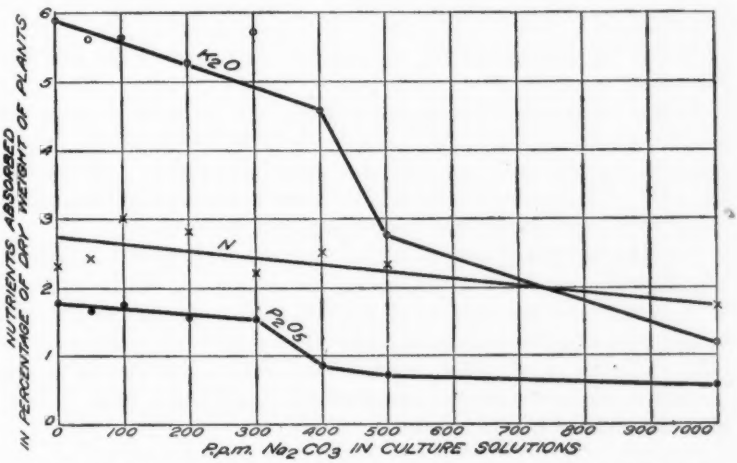

FIG. 8.—Graphs showing the effect of sodium carbonate on the absorption of nutrients by wheat seedlings.

It has been shown by Le Clerc and Breazeale[1] that there is a very marked absorption of potash by sprouting grain seedlings. As potash appears to be vitally concerned in the decomposition and translocation

[1] Le Clerc, J. A., and Breazeale, J. F. Translocation of plant food and elaboration of organic plant material in wheat seedlings. U. S. Dept. Agr. Bur. Chem. Bul. 138, 32 p., 2 fig. 1911.

of carbohydrates, any salt such as sodium carbonate, which would interfere with the absorption of potash at this stage of growth would seriously handicap the development of the plant.

It will be recalled that calcium carbonate was present in the culture solutions in the solid phase. It will be shown in another paper that appreciable quantities of sodium carbonate are formed through the reaction of sodium chlorid and sodium sulphate with calcium carbonate, and the resulting hydrolysis is greater with sodium sulphate than with sodium chlorid. This is in harmony with the greater activity shown by sodium sulphate in depressing the absorption of potash and phosphoric acid and suggests that the effect observed in the case of sodium chlorid and sodium sulphate may be in part due to the small amounts of sodium carbonate formed through reaction with the calcium carbonate.

CONCLUSIONS

Sodium chlorid, sodium sulphate, and sodium carbonate added to nutrient solutions in concentrations up to 1,000 p. p. m. do not measurably affect the nitrogen absorbed from culture solutions by young wheat plants.

Sodium chlorid in concentrations up to 1,000 p. p. m. does not affect the absorption of phosphoric acid, but decreases slightly the absorption of potash.

Sodium sulphate in concentrations of 1,000 p. p. m. depresses the absorption of potash and phosphoric acid to approximately 70 per cent of that of the control cultures, expressed in percentage of dry weight of the plants.

Sodium carbonate in concentrations of 1,000 p. p. m. reduces the absorption of potash to 20 per cent of that of the control and the absorption of phosphoric acid to 30 per cent of that of the control. The depressing effect of sodium carbonate is in evidence in concentrations as low as 100 p. p. m., and is marked in concentration of 300 p. p. m.

The relative effect of sodium sulphate and sodium chlorid in depressing the absorption of potash is directionally the same as the relative hydrolysis resulting from the reaction of the two salts with the calcium carbonate present in the culture solution. This suggests that the observed effects in the case of sodium sulphate and sodium chlorid may be due in part to the accumulative action of the slight amounts of sodium carbonate formed in this reaction.

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